



Lesson 3: Density

Students explore the properties that allow objects and liquids to float and use this information to infer the composition of the Earth's layers.



Main Lesson Concept: Density determines whether a substance will float on another substance and thus affects the composition of Earth's layers.



Scientific Question: What allows a substance to float? What determines the composition of Earth's layers?

Objectives		Standards
<ul style="list-style-type: none"> Students will explain the properties that allow a substance to float. Students will write an essay describing the thickness, composition, and density of the layers of the Earth, and will explain how density relates to the Earth. 		Addresses: 2061: 4D (6-8) #2 NSES: B (5-8) #1.1
Assessment	Abstract of Lesson	
Density of the Interior of the Earth essay and inquiry activity write-ups in Astro Journal.	Students use the inquiry process to determine what causes an object or liquid to float. They observe that an object or liquid of less density will float on a liquid of greater density. They will observe that when a liquid of lesser density is beneath a liquid of greater density, the liquid of lesser density will move on top of the other liquid. Students then conduct research and write an essay about the thickness, composition, and density of the layers of the Earth's interior, inferring that core is the most dense, while the crust is the least dense.	
Prerequisite Concepts		Major Concepts
<ul style="list-style-type: none"> Heating and cooling may cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions. (2061: 4D (3-5) #1) Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions. (2061: 4D (6-8) #3, Astronomy Lessons 4 and 5) Different substances require different amounts of pressure or temperature to change states because of the strengths of their molecular bonds. (Geology Lesson 2) Mass is the amount of matter in an object or substance. Volume is the amount of space an object or substance takes up. 		<ul style="list-style-type: none"> Density is the amount of matter in a certain unit of volume or space, and it is the measure of how tightly packed molecules are within a substance. Substances of greater density will sink below those of lesser density. As you go deeper into the Earth, the density of the materials increases. A change in density can affect the movement of matter.





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
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Suggested Timeline (45-minute periods):

Day 1: Engage, Explore Part 1, and Explain Part 1 sections

Day 2: Explore Part 2 and Explain Part 2 sections

Day 3: Extend section

Day 4: Evaluate section (approximately 20 minutes)



Materials and Equipment:

- A class set of Astro Journal Lesson 3
- Books, encyclopedias, geology textbooks, computer with Internet connection, or other resources on the interior of the Earth
- Chart paper

Materials for Float or Sink Activity (teacher demo or each group will need the following):

- A glass or graduated cylinder about 3/4 full of water
- A variety of sphere-shaped objects, many of which are of similar size but composed of different materials such as rubber balls, marbles, and clay balls
- 2 sphere-shaped objects of the same mass but different size such as a polystyrene foam ball (similar to Styrofoam™) and a bead
- A balance scale or other scale

Materials for Density Activity (each group will need the following):

- 5 beakers, each half full of one of the following liquids (food coloring in each liquid is optional)
 - Cooking oil
 - Water
 - Molasses
 - Hair conditioner
 - Vinegar
- 2 transparent empty containers such as jars, glasses, or clear plastic cups

Preparation:

- Duplicate a class set of Astro Journal Lesson 3.
- Gather materials for demonstrations and activities.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

Differentiation:

Accommodations

For students who may have special needs, have them work with a partner on their Astro Journal writing or report orally to the teacher. Instead of writing an essay, have them draw the interior of the Earth and label each with descriptions of the composition, thickness, and relative density.

Advanced Extensions

Have students determine the density of each of the objects and substances using the formula: $\text{Density} = \text{Mass}/\text{Volume}$. The unit for density is g/mL. Students can then compare the densities they figured mathematically to the predictions they made about which objects were the most and least dense and which liquids were the thickest and thinnest.





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Engage

(approximately 5 minutes)

1. Review states of matter concepts from Astronomy Lessons 3 through 5.

- Question: What are the three states of matter?
- Answer: *The three states of matter are solid, liquid, and gas.*
- Question: What causes each of these states to be different?
- Answer: *The amount of energy affects the movement of the molecules and their ability to break the bonds between them and other molecules. In solids, molecules have less energy and their movement is not enough to break the bonds. Liquids have more energy, increasing the movement and breaking some of the bonds. In gases the energy has increased enough that molecules can completely break the bonds between them and other molecules.*
- Question: What are the differences between the movement of molecules in solids, liquids, and gases?
- Answer: *The molecules in solids only vibrate. In liquids, the molecules slide past each other. In gases, the molecules spread out freely.*

2. Review the causes of changes in states of matter from Astronomy Lesson 5 and Geology Lesson 2.

- Question: In past Astronomy and Geology lessons, what did you observe that causes matter to change its state?
- Answer: *A change in temperature or pressure causes matter to change state.*
- Question: If you increased the pressure on a substance, what effect could this have on the substance?
- Answer: *The temperature of the substance could increase.*
- Question: What would happen to the molecules in the substance as a result?
- Answer: *The molecules in the substance would begin moving more quickly.*
- Say: We know the effects of pressure and temperature on the molecules in a substance. Today we are going to look at how the packing of molecules in a substance determines if it will sink or float.

3. Draw on students' prior knowledge of things that float.

- Question: What things have you seen float?
- Answer: *(Accept all reasonable answers.)*
- Question: What do you think might cause these things to float?
- Answer: *(Allow students to think about this and share their ideas.)*

4. Introduce the purpose of the lesson.

- Say: Things float on Earth, and parts of the Earth's interior also float. In the Geology Training Module, you learned that the lithosphere floats on the asthenosphere (upper part of the mantle). In this lesson, you will see how floating affects the Earth's layers, and later we will see why this floating supports human survival on our planet.

5. Introduce the Scientific Questions.

- Say: The Scientific Questions we will be exploring in this lesson are:
 - What allows a substance to float?
 - What determines the composition of Earth's layers?
- Say: We are going to focus on the first question in our first activity.





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Explore

Part 1 - (approximately 25 minutes)

1. Lead students in Float or Sink Activity.

Note to Teacher: You may want each group to do the following activity on their own rather than doing a demonstration, depending on the availability of materials. If you do the activity as an interactive demonstration, include one object for each group, and have each group take turns measuring the mass and volume of each object before switching to a new object. Alternatively, each group could measure just one object and share the data with the class.

- Show students a glass or graduated cylinder about 3/4 of the way full of water.
- Show students a variety of objects that will be dropped into the water. Pass the objects around so that the students can feel how heavy or light the objects are and so they can make other observations about the properties of each object.

Note to Teacher: We recommend using balls or other sphere-shaped objects for this demonstration. It is best to use balls that are the same size and made out of different materials, as well as balls that are different sizes. Ideas of balls that you may have available are marbles, rubber balls, polystyrene foam balls, and balls made of clay.

- Have students make a prediction/hypothesis to the first question (What allows a substance to float?) in the Float or Sink Activity section of their Astro Journals.

Opportunity for Open Inquiry: Students can use the question above to develop a student-directed experiment. Have students design and carry out their own experiment to answer the question. Students probably will not identify density as the characteristic that determines if an object can float, but they will likely make some observations that will counter their misconceptions and thus be more open to this concept. If you choose to do this Open Inquiry, skip down to the Explain Part 1 section once your students have completed their experiments. You may have to modify the discussion in the Explain section slightly to draw out students' conclusions about their experiments, but the discussion includes some important conclusions that should be drawn from either activity.



MISCONCEPTION: Students may think that mass determines whether an object floats or sinks—that lighter objects float, while heavier objects sink. To confront this misconception, it's important to include at least two balls of equal mass but different density, such as a large polystyrene foam ball and a small bead. It would be even better if a bead that was less massive than the polystyrene foam ball were included. The following activity will help to confront this misconception.

- Ask students to share their predictions about which objects will float. List student predictions on the board and discuss why they think they will float.
- In the Data Chart in their Astro Journals, have the students list the names of the objects and whether or not the objects will float. Then have students measure and record the mass and volume of each object.





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
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Note to Teacher: The mass of each ball can be measured using a balance scale, which compares the weight of the object to weights with predetermined masses. If balance scales are not available, any scale can be used. The volume of each object could be measured by submerging each ball in a graduated cylinder of water and recording the difference in the water level. In the process of measuring volume, some objects may float. Students can push the object down with a toothpick or other utensil. Measuring mass and volume will help the students to think about whether there is a connection between mass and volume and whether objects float or sink.



MISCONCEPTION: Students often have trouble understanding the difference between mass and weight. Discuss with students that mass is the amount of matter in an object, and weight is the amount of mass multiplied by gravity. Weight is the amount of force with which an object is attracted toward the Earth. Students often think of weight as "felt weight." Since weight is really a force, it should really be measured in Newtons, but because the force of gravity is the same for everything on Earth, it has become acceptable to measure weight in kilograms or pounds. Thus, when we "gain weight, the force of gravity doesn't become stronger, but rather we have added mass to our bodies. Emphasize with students that they are measuring the amount of matter in each object. Model this language with them by asking questions, such as "Which object has the most matter?"

- Complete the demonstration by dropping each object into the glass or graduated cylinder.
- Have students record which items floated and any other observations in their Astro Journals. Make a list on the board of the objects that floated and those that did not.
- Have students complete the questions in their Astro Journals for this activity.



Explain

Part 1 - (approximately 15 minutes)

1. Have students share their observations about dropping the balls into the same container.

- Question: What observations did you make during this demonstration?
- Answer: (Accept all reasonable answers. Students may have observed that in some cases, objects with more mass sank, while objects with less mass floated.)
- Question: What observations did you make about the properties of the objects prior to them being dropped in the water?
- Answer: (Accept all reasonable answers. Depending on the objects you used, students may respond that some of the objects had different volumes, while some objects had the same volume but had different masses.)

2. Guide students in their conclusions of what causes an object to float.

- Make two lists of the objects with the class. In the first list, write the objects in order from the least massive to the most massive. In the second list, write the objects in order from the lowest volume to the greatest volume. Circle the objects that floated in each list.
- Question: Looking at these lists, what observations can you make?
- Answer: (Answers will depend on the objects you used; however, students should observe that objects of relatively low mass but relatively high volume [such as a polystyrene foam ball] float.)





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-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--

- Question: Do you think that mass is the only factor that determines whether an object will float? Why or why not?
- Answer: *No, mass is not the only factor. There are objects of the same mass or even less mass than the polystyrene foam ball that don't float, so volume seems to also be a factor.*
- Question: What do you notice when you compare the polystyrene foam ball with the bead of the same mass?
- Answer: *The polystyrene foam ball is larger than the bead.*
- Question: How can two objects be the same mass, if one is larger?
- Answer: *In the larger object, the matter must be more spread out.*

Note to Teacher: If students don't come up with this answer, you might have a small group act out density, by having them stand close together and then spread out. Ask them, if the number of people (or mass) has changed. Guide them to see that the mass doesn't change, just how close together they are. Help them to connect this to the molecules that make up the polystyrene foam ball and the bead.

2. Discuss density with students.

- Question: What can you tell me about the molecules in the bead compared to the molecules in the polystyrene foam ball?
- Answer: *The molecules in the bead are more tightly packed together than the molecules in the polystyrene foam ball.*
- Question: If the molecules are more tightly packed together in the bead, are there more or less molecules in each unit of space than compared to the molecules in the polystyrene foam ball?
- Answer: *There are more molecules in each unit of space.*
- Say: The amount of matter (mass) in a certain unit of volume or space is called density.
- Question: When comparing the bead to the polystyrene ball, which object has more mass in a smaller amount of space?
- Answer: *The bead has more mass in a smaller space.*
- Say: So we say that the bead is denser than the polystyrene foam ball.
- Question: So what can you say about what causes objects to float?
- Answer: *Objects of lower density float.*

Note to Teacher: Density is mass divided by volume. You may want to have students calculate the density of each object to see how they compare. An object that is less dense has its mass spread out over a larger surface area, which allows it to float; thus, the shape of an object is also a factor in allowing an object to float. This is what enables large ships made of steel to float. Shape and surface area, however, are not the focus of this lesson. The focus here is on why the layers of the Earth float on each other and what causes some substances to float upon other substances. You may want to further explore other characteristics, such as surface area and shape, that allow solids to float in liquids.





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--



Explore

Part 2 - (approximately 20 minutes)

1. Lead students in the Density Activity.

Note to Teacher: This activity is written as a small group activity, but it can also be used as a teacher demonstration.

- Provide students with five beakers each half full of one of the following liquids: cooking oil, water, molasses, hair conditioner, and vinegar.

Note to Teacher: Some of the liquids may be very similar in color. You may want to add different food coloring to each liquid to help the students differentiate between the liquids.

- Have students observe the liquids and record these observations in their Astro Journals. Encourage students to observe the consistency of each liquid by touching the substance with their fingers and moving the beaker around to see how the liquid moves.
- Have students share their observations about the liquids.
- Question: What are some of the similarities of the substances? What are some of the differences between the substances? Explain.
- Answer: (Accept all reasonable answers. Students may explain that all of the substances are liquids and that there is the same volume or amount of each substance. Students may explain that the liquids have different colors, textures, and thickness.)
- Question: What causes some of the liquids to be thicker than others? How might the molecules of thicker substances differ from thinner substances?
- Answer: The molecules in the thicker liquid are more tightly packed together than in the thinner liquid. (Thicker liquids are denser than thinner liquids.)
- Question: What do you predict would happen if you poured all five liquids into one container?
- Have students record their predictions in the Density Activity section of their Astro Journals.
- Give students an empty transparent container.
- Have students slowly pour half of each liquid into one container and observe. (They will need the other half of each liquid for the second part of this activity.)

Opportunity for Open Inquiry: Students could develop their own experiment to test the effects of pouring in one liquid at a time, pouring all of the liquids in at the same time, allowing the container to sit with the poured liquids in it for a period of time, or using additional liquids.

- Have students record their observations in their Astro Journal.





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-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--



Explain

(approximately 25 minutes)

1. Have students share their observations about pouring the liquids into the same container.

- Question: What observations did you make when you poured all five liquids into the same container?
- Answer: *The thickest liquid went to the bottom of the container and the thinnest liquid floated on top of the other liquids.*
- Question: Why do you think one liquid went to the bottom of the container?
- Answer: *(Accept all reasonable answers. Students will probably say that the liquid at the bottom is denser than the other liquids.)*
- Question: If one liquid is denser than all the other liquids, what can you tell me about the molecules in that liquid?
- Answer: *The molecules in the denser liquid are more tightly packed together than the molecules in the other liquids.*
- Question: If the molecules are more tightly packed together in the densest liquid, are there more or less molecules in each unit of space than compared to the molecules in the thinnest liquid?
- Answer: *There are more molecules in each unit of space.*
- Question: Of the liquids you tested, which do you think have a high density?
- Answer: *The liquids that have a high density are molasses and conditioner.*
- Question: Would the liquids separate like this no matter the order in which you put them?
- Answer: *(Allow students to share their ideas.)*

2. Guide students in the second part of the Density Activity.

- Have students predict in their Astro Journal what would happen if they poured the least dense liquid in first, followed by two denser liquids.
- Have students pour the least dense liquid into another transparent container first. Then have the students slowly pour two other liquids from this activity into the same container.
- Have students record their observations in their Astro Journals.
- Have students share their observations about what happened when they poured the least dense liquid into a container first, and then poured two other liquids from this activity into the same container.
- Question: What did you observe when you poured the least dense liquid into the container first, followed by two other liquids from this activity?
- Answer: *Students should have observed that the least dense liquid floated on top of the other two liquids even though the least dense liquid was poured first.*
- Question: What causes this movement of liquids?
- Answer: *This movement of liquids is caused by the differences in the densities of the liquids.*





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--

3. Discuss with students the connection between the Density Activity and the Float or Sink Activity.

- Say: Remember the activity we did at the beginning of this lesson using a graduated cylinder and balls.
- Question: How would you describe the density of the marble? Why?
• Answer: *The marble has a high density because the molecules are tightly packed together.*
- Question: How would you describe the density of the water? Why?
• Answer: *The water has a lower density than the marble because the molecules are not as tightly packed. There are not as many molecules in a certain amount of space.*
- Question: Did the marble float or sink when it was dropped in the glass of water?
• Answer: *The marble sank when dropped in a glass of water.*
- Question: What do you think would happen if we dropped the marble into the container in which you combined two liquids from the Density Activity?
• Answer: *Students should respond that the marble would sink to the bottom.*
- As a demonstration, drop a marble into a transparent container containing the liquids from the Density Activity.
- Have students share their observations about this demonstration. Students should discuss that the marble moved through the liquids to the bottom of the container.
- Question: What do you think would happen if we dropped the polystyrene foam ball into a container containing two of the liquids from the Density Activity?
• Answer: *Students should respond that the polystyrene foam ball would float.*
- As a demonstration, drop a polystyrene foam ball into a container containing the liquids from the Density Activity.
- Question: Do you think the polystyrene ball is more or less dense than the marble?
• Answer: *Students should respond that the polystyrene ball is less dense than the marble.*
- Question: Can you relate the information you learned from the Float or Sink Activity with the information you learned from the Density Activity to explain why the marble sank when dropped in the liquids?
• Answer: *The marble sank when dropped in water because it was denser than the liquids.*
- Question: Why did the polystyrene foam ball float in the liquids?
• Answer: *The polystyrene foam ball floated because it was less dense than the liquids.*
- Question: What must be true for a substance to float?
• Answer: *For a substance to float, it must be less dense than the substance it is floating upon.*





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--



Extend/Apply (approximately 45 minutes)

- 1. Discuss with students that they can use their knowledge of density to understand the composition of the layers of the Earth.**
 - Say: What you just learned about density and why substances float can help us understand the make-up of the layers of the Earth.
 - Question: In the Density Activity, where did the densest substances go?
• Answer: *The densest substances moved to the bottom of the container.*
 - Question: In the interior of the Earth, where do you think the densest substances would be?
• Answer: *The densest substances would be at the center of the Earth.*
 - Question: Which layer of the Earth do you think is the densest?
• Answer: *The core is the densest.*
 - Question: Why is the core the densest layer of the Earth?
• Answer: *The core is the densest because as the Earth formed, the densest substances sunk towards the center, thus forming the core.*
 - Question: How would you describe the density of the mantle compared to the other layers? Explain your reasoning.
• Answer: *The density of the mantle would be less dense than the core, but it would be denser than the crust. Because the mantle is on top of the core, the mantle must be less dense than the core. Because the mantle is under the crust, the mantle must be denser than the crust.*
 - Say: Each of the layers of the Earth is composed of different materials and has a different thickness. When the Earth was forming, all of the materials were mixed up.
 - Question: What do you think happened to the materials inside the Earth over time?
• Answer: *Students should explain that over time the materials were separated by gravity, with the densest materials in the center and the least dense materials on top.*
- 2. Have students complete the Density of the Interior of the Earth Activity.**
 - Say: In this activity, you will use your knowledge from this lesson, as well as information you get from conducting research, to write an essay about each of the Earth's layers, why the layers are in the order that they are, and how the Earth's layers compare to the liquid layers in the Density Activity.
 - Introduce the activity by reading over the directions with the students.
 - Have students conduct their research using the Internet, encyclopedias, geology textbooks, or other resources.

Note to Teacher: You may want to have students finish their essays as homework.





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--



Evaluate

(approximately 20 minutes)

1. Have students share and discuss their essays for the Density of the Interior of the Earth Activity.
2. Discuss students' responses in their Astro Journals to ensure they have mastered the major concepts.
 - Question: What is the thickness and composition of each of Earth's layers?
• Answer: On average, the crust is about 40 kilometers thick (almost 25 miles). The mantle is about 2900 kilometers thick (about 1800 miles). The core is almost 3500 kilometers thick (about 2150 miles).
 - Question: How does density affect the composition and order of Earth's layers?
• Answer: The core is composed of iron and nickel, which is the densest layer. The crust is composed mostly of silicate rock, which is the least dense. The mantle is composed of rock that has a density between the core and crust. The denser materials sunk down to the middle of the Earth, while the materials of lesser density float on top.
 - Question: How would you compare the molecules in each layer?
• Answer: The molecules in the core are more tightly packed together than in the mantle and core because the materials are very dense. As you travel away from the core to the crust. The molecules are not as tightly packed and have more space between them.
 - Question: How can density affect movement?
• Answer: When a substance that is less dense is under a substance that is denser, the less dense substance rises or moves above the other substance.
 - Question: How are the Earth's layers like the liquid layers in the Density Activity?
• Answer: (Accept all reasonable answers. Answers may include that just as the liquids separated into most dense to least dense layers, so are the Earth's layers separated into most dense to least dense layers. Just as liquids of lower density rise above those of greater density, so do the materials inside the Earth.)
 - Question: How are the Earth's layers different from the liquid layers in the Density Activity?
• Answer: (Accept all reasonable answers. Answers may include that the Earth's layers are solid and are much larger in mass.)
3. Collect students' Astro Journals and evaluate them to ensure that they have each mastered the major concepts:
 - Density is the amount of matter in a certain unit of volume or space, and it is the measure of how tightly packed molecules are within a substance.
 - Substances of greater density will sink below those of lesser density.
 - As you go deeper into the Earth, the density of the materials increases.
 - A change in density can affect the movement of matter.
4. Bridge to next lesson.
 - Say: Today we learned about density and how density affects the make-up of the layers of the Earth. In the next lesson, we will look at how density affects movement inside the Earth.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.





Name:

Date:

Density Activity

Directions

1. Slowly pour all five liquids into one container.
2. Record your observations below.

3. What observations did you make when you poured all five liquids into one container?

Directions

1. Make your hypothesis/prediction below.
2. Pour the least dense liquid into a container first.
3. Slowly pour two other liquids from this activity into the same container.
4. Record your observations below.?

4. **Hypothesis/Prediction:** What do you predict will happen if you pour the least dense liquid into the container first?

5. What observations did you make when you poured the least dense liquid into a container first, followed by two other liquids?

Astro Journal Geology Lesson 3: Density

Class/Period:

Density Activity

1. Data Chart:

Liquids	Observations
Oil	
Water	
Conditioner	
Vinegar	

2. **Hypothesis/Prediction:** What do you predict will happen if you pour all five liquids into one container?





Geology Training Module	Temperature, Pressure, and the Earth	Density	Convection in the Earth	Plate Tectonics and Volcanism	Carbon Cycle and Life	Magnetic Field and Life	Geology Conclusion: Summarizing Learning
-------------------------	--------------------------------------	---------	-------------------------	-------------------------------	-----------------------	-------------------------	--

Density of the Interior of the Earth Activity

Directions:

1. Use your knowledge of density from this lesson.
2. Conduct research about the composition and thickness for each of Earth's layers.
3. Look for similarities and differences between the liquid layers in the Density Activity and the information you learn about the composition and thickness of Earth's layers.
4. Write your essay. Be sure to include the information below.

Your essay must include information on:

- The thickness and composition of each of the three main layers of the Earth.
- A comparison of the molecules in each layer.
- How density affects the composition and the order of Earth's layers.
- How density can affect movement within the Earth.
- Similarities and differences between the Earth's layers and the liquid layers in the Density Activity.

Your drawing and description will be evaluated using the following rubric:

4	<ul style="list-style-type: none"> • Essay clearly and accurately explains the density of the interior of the Earth. • Essay has all required parts and uses excellent reasoning to create an exceptionally powerful and detailed explanation.
3	<ul style="list-style-type: none"> • Essay clearly and accurately explains the density of the interior of the Earth. • Essay has all required parts and uses good reasoning in explanations.
2	<ul style="list-style-type: none"> • Essay is not completely clear or accurate in explaining the density of the interior of the Earth. • Essay has most required parts and uses some good reasoning in explanations.
1	<ul style="list-style-type: none"> • Essay is not clear or accurate in explaining the density of the interior of the Earth, is missing several parts, and uses little or no good reasoning.

